DETERMINATION OF GAS CONTENT OF COAL

A THESIS SUBMITTED IN PARTIAL FULFILLMENT

OF

THE REQUIREMENTS FOR THE DEGREE OF

BACHELOR OF TECHNOLOGY

IN

MINING ENGINEERING

BY

C V KRISHNA PRASAD

108MN002

DEPARTMENT OF MINING ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY
ROURKELA - 769008
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UNDER THE SUPERVISON OF

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National Institute of Technology

Rourkela

CERTIFICATE

This is to certify that the thesis entitled "**Determination of Gas Content of Coal**" submitted by **Sri C V Krishna Prasad** (Roll No. 108MN002) in partial fulfilment of the requirements for the award of Bachelor of Technology degree in Mining Engineering at National Institute of Technology, Rourkela is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter substantiated in the thesis has not beensubmitted to any other University/Institute for the award of any Degree or Diploma.

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Date:

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Date: C V Krishna Prasad

ABSTRACT

Introduction

Coalbed gas content measurements are normally carried to estimate methane emission rates into mine workings and for coalbed methane gas recovery applications. Techniques of gas content determination are broadly divided into two categories, viz. direct methods which actually measure the volume of gasreleased from a coal sample sealed into a desorption canister and indirect methods based onempirical correlations, or laboratory derived sorption isotherm gas storage capacity data. Direct gas content determination techniques are sub-categorised into quick-crushing and extendeddesorption methods. In quick-crushingmethods the coal sample is crushed soon after collection to release all the desorbablegas. Extended desorptiontechniques are most commonly used for recovery applications and resource assessment whereinformation on desorption rates is usefulfor fundamental coalbedmethane research, andfor reservoir modelling.

CBM in India

India, having the fourth largest proven coal reserves in the world, holds significant prospects for exploration and exploitation of CBM.India has one of the most investor friendly CBM policies in the world. In our country a totally transparent and fair bid evaluation criteriahas been evolved and is in place. There is, therefore, a huge opportunity for potential CBM investors in India.Commercial production of CBM has already commenced in Raniganj (South) CBM block in West Bengal. Efforts are also being made in Shoagpur blocks in Madhya Pradesh and Jharia block in Jharkhand for commencement of commercial production at the earliest.It is expected that CBM production in India will go up to 7.4 MMSCMD by the year 2013 - 14.

Experimental Investigation

The freshly blasted coal samples were immediately sealed in a container then brought to the laboratory for experimentation. The samples were crushed and put into the desorption canister. The sample was heated at a very low heating rate to allow desorption of gas. The pressure developed inside the canister was noted down and then the valve of the canister was opened and gas was collected by downward displacement of water. The sample was allowed to desorb until a low desorption rate cut-off point was reached.

Results

As a part of the project work, extended desorption method was followed to find out the gas content of block samples brought from 10 different mines of MCL. The results are shown below in table 1.

Table 1: Gas Content of Coal Samples

Sample no.	Colliery/Mine	Gas content(in m^3/tonne)
1	Lakhanpur	0.050
2	Basundhara	0.248
3	Kulda	0.206
4	Nadira colliery	0.325
5	Lingaraj	0.130
6	Bhubaneshwari	0.104
7	Dera colliery	0.352
8	Jagannath	0.204
9	Ananta	0.101
10	Bharatpur	0.152

DiscussionsandConclusion

It could be observed from the experimental investigation that the gas content of coal samples varied from 0.05 m^3/tonne to 0.352 m^3/tonne. Coal samples collected from underground mines had greater amount of residual gas content as compared to the rest this corroborates the fact that gas content of coal increases with depth. If the gas content is found to be very high then vertical bore holes may be put up to extract methane for a variety of commercial applications, starting from domestic heating to generation of electricity

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1. Diamond W.P. and Schatzel S.J., (1998), "Measuring the Gas Content of Coal: A Review", International Journal of Coal Geology, Vol.35 (1), pp.311-331

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CHAPTER 1

INTRODUCTION

CHAPTER 1

1. INTRODUCTION

The build-up of methane in underground coal mines is a safety problem in the India and around the world. Determining the quantity of methane enclosed within a coalbed can be avital step in assessing the potential severity of gas problems in a new mine or in unmined areas of an existing mine. The gas content of a seam can be tested during the exploration stage from core drilled samples. An early estimation of the potential for methane emission problems offers the greatest amount of lead time to take account of longer term gas drainage techniques into the development plan of mines. Once mining is started, gas content testing can be used at times to assess gas content conditions ahead of mining. Although mine safety was initially the primary purpose for measuring the gas content of coalbeds, the prospective for commercial coalbed methane production has led toabetter interest in this technology.

Methane occurs with other hydrocarbons, $C0_2$, N_2,0_2, and He. It is a usual by-product of the coal-forming process.While much of the gas formed during coalification migrates away from thecoal; asubstantial portion is retained in the coal and neighbouring rocks. Somefree gas is present in cracks and fractures, but maximum is adsorbed on theinternal surface ofmicropores within the coal. The volume of gas that thecoal contains depends primarily upon temperature, pressure, moisture content, and adsorptive capacityof the coal. Porosity, Permeability, distance from the outcrop, and degree of fracturing of the coal and neighbouring rocks may also affect the gas content of a coalbed.

During coal mining 60 to 80% of the gas contained within the coal is discharged intothe mine atmosphere, where gas amassing creates an explosion hazard. The orthodox method of dealing with this hazard is through ventilation, which adulterates the emitted methane with air to non-explosive concentrations and carries it to the surface. In near future when we have to mine higher rank coal beds at greater depths then there is a possibility that ventilation will not be sufficient to dilute the amount of methane emitted from those beds. It may be essential to drain methane from the coal seamprior to mining. If the drained gas is to be sold as a fuel, it will beobligatory to assess the amount of gas that can be recovered from thecoal seam.

Gas content is probably the most important parameter to be quantified in order to characterise a coal seam both from mine safety and gas recovery viewpoints. Worldwide, numerous direct

and indirect methods of determining the gas content of coal are practiced. The direct method is based on the direct measurement of gas volume evolved from coal whereas the indirect method consists of measuring other coal properties and using the established relationships between these parameters and gas content to evaluate the latter. The two principal variants of the direct method are the slow desorption technique and the quick crush method.

1.1 OBJECTIVES

Keeping the above problem in mind, the work was planned with the following objectives:

- Study of occurrence and emission of methane.
- Study of status of CBM extraction in India.
- Collection of block/core samples from mines.
- Determination ofgas content of collected coal samples.
- Correlation study of intrinsic properties of coal and its gas content.

CHAPTER 2

LITERATURE REVIEW

CHAPTER 2

2. LITERATURE REVIEW

A lot of studies and research works have been carried out by different researchers in the past for assessment of gas content of coal. Some of these works have been summarized below.

Kim (1977) Estimated Methane Content of Bituminous Coalbeds from Adsorption Data. By assuming a standard moisture and ash content, and using the hydrostatic head to estimate pressure, a graph of rank and depth versus gas content was constructed. In his discussions he stated that In mining, the amount and rate of methane released depends on factors such as rib extent, age of the mine, production rate, gob area, and permeability of the coal.

Saghafi et al. (1998) carried out a lot of research to find the Accuracy of measurement of gas content of coal using rapid crushing techniques. The rapid crushing technique for the measurement of gas content of coal comprises of accelerating the rates of gas desorption from coal through crushing. This technique permits the determination of gas content in the space of hours rather than days or weeks as required for the traditional slow desorption technique. The crushing technique is used chiefly when gas content determinations are immediately required for mine safety purposes.

Barker et al. (2004) analysed the canister desorption results of samples from Fort Yukon bore well, Alaska. Coal gas content study was done by re-entering a 1994 USGS core hole to sample coal found in Tertiary strata of the Yukon Flats Basin. Methane adsorption isotherms were measured by reintroducing methane to a coal and measuring the equilibrium gas content at a given pressure and at a constant temperature.

Ramaswamy (2007) reviewed literature and solicited opinions of industry experts throughresponses to a questionnaire. He identified thirteen geologic parameters (and their ranges of values) that are assessed when selecting CBM drilling, completion and stimulating applications. Those were coal thickness, number of seams, areal extent, dip, depth, rank, gas content, formation pressure, permeability, water saturation, and compressive strength, as well as the vertical distribution of coal beds and distance from coal reservoirs to fracture barriers or aquifers. He identified the optimum CBM drilling, completion and stimulating practices for specific combinations geologic parameters and offered the following conclusions:

- Drilling, completion and stimulation methods used in the CBM reservoirs differ from basin to basin, and aerially within basins, owing to variations in geologic setting and coal seam properties.
- Reservoir parameters and the corresponding range of values, that influence the selection and the success of horizontal wells are:
  - thickness of 3 Ft – 20 Ft;
  - areal extent of the coal ≥ 1500 Ft;
  - dip of the coal seam < 15 degrees; and
  - Depth of 500 Ft – 4000 Ft.

- For CBM wells that encounter more than one coal bed, multi-stage fracturing is the best stimulation method, if the seams are separated by a distance of more than 40 Ft.

Singh and Saxena (2007) observed that the CBM potential of India is highly encouraging in nature, but the main impediments on the way to exploit these resources are lack of technical understanding and experience, insufficient training and education skills, lack of advanced technology suited to mining and geological conditions and little understanding of the market conditions and commercial issues. In India, 16% of the area is identified for exploration, 22% of the area in which the exploration has been initiated consists 62% area of Gondwana (35000 sq. km is unexplored). Total coal bearing area is of 35400 sq. km consisting of 44 major coal and lignite fields distributed in 12 states depicting the prognosticated CBM Resources of 162 TCF (4.6 TCM).

Recently govt. of India further announced 10 blocks in order to explore and produce CBM they are:

i. Rajmahal coal fields, Jharkhand – avg. gas content 5-6 m^3/t. The CBM resource of the block is estimated at 158 BCM.
ii. Birbhum coal fields, west Bengal – resource 50 BCM.
iii. Shoagpur coal fields, M.P – gas content 6m^3/t, estimated CBM resource – 16.72 BCM.
iv. Singrauli main basin CBM blocks gas content 8.9 – 9.7 m^3/t, estimated CBM resource – 31 BCM.
v. Tatapani – Ramkola Coalfield, Chattisgarhgas content 7.4 – 8.1 m^3/t, estimated CBM resource – 53.78 BCM.

vi. Mand-Raigarh Coalfield, Chhattisgarh gas content 4.5 – 5.5 m^3/t, estimated CBM resource – 57.2 BCM.

vii. Northern Godavari Valley Coalfield, Andhra Pradeshgas content 4 – 5 m^3/t, estimated CBM resource – 29.65 BCM within a depth range of 450 – 1500 m.

viii. Barmer Basin, Rajasthangas content 3 – 4 m^3/t, estimated CBM resource –82 BCM and 38 BCM in two blocks.

According to them the era of CBM Energy in the country would bring the green environment and a safe future with the possible reducing greenhouse gases effect on the earth together with the needed energy securities for sustainable growth.

Mora (2007) made a comparative study of computational methods for CBM production performance. In his thesis he used different tools available in the gas industry for CBM reservoir analysis, such as numerical reservoir simulators and semi-analytical software programs, to comprehend the differences in production performance when standard input data is used. In his study he also analysed the effect of sorption time (for modelling the diffusion process) on the gas production performance for CBM wells.

Sharma et al. (2008) studied the different methods of methane degasification like vertical wells, gob wells, horizontal boreholes, and cross-measure boreholes. They enlisted the economic benefits of coal-bed methane (CBM) drainage and potential uses of coal mines methane obtained from Coal bed methane (CBM) drainage.

Mathews (2010) carried out a number of experiments and concluded that for thedegasing of coal seams, either prior to mining or in unwinnable seams to obtain CBM; it is the cleat frequency, aperture, connectivity and mineral occlusions that influencecoals permeability to gases. Unfortunately many potential coal beds have limitedpermeability, thus they are often marginal for economic methane extraction. Theyalso present a challenge in the case of enhanced coal bed methane extraction, withconcurrent carbon dioxide sequestration, due to limited carbon dioxide injectivity.Microwave energy can, in the absence of confining stress, induce fractures in coal.Here creation of new fractures and increasing existing cleat apertures via short bursts,high-energy microwaves was evaluated for both hydrostatically stressed andunstressed North American bituminous coal cores. A microwave-transparent argongas pressurized (1000 psi) polycarbonate vessel, simulating hydrostatic stress of 1875foot depth was utilized. Cleat/fracture volume, following microwave exposureincreased from 1.8 % to

16.1% of the unconfined core volume. Similar observationsof fracture generation and aperture enhancement in coal were also determined forexposure under hydrostatic stress conditions.an existing cleat aperture increased from0.17 mm to 0.32 mm, after short microwave-bursts occurring under simulatedhydrostatic stress conditions.
He concluded that microwaves have the potential to enhance the communicationbetween the horizontal wellbore and existing cleat network, in coal seams at depth,for improvised gas recovery.

Lin (2010)found that primary recovery by reservoir depressurization is successful, but generally produces only about half of the gas in place. Gas (carbon dioxide, nitrogen, or mixtures of these components) injection is potentially an efficient technique both to enhance coalbed methane recovery as well as sequester greenhouse gases (mainly carbon dioxide) in subsurface geological sites. Due to the special features of coalbed reservoirs and the nature of gas retention in the reservoirs, there are unique issues that need to be taken into account when designing field operations and conducting numerical simulations of gas production and injection in coalbed methane reservoirs. One issue of particular interest is the permeability evolution of the reservoirs as gas is produced or injected. Two mechanisms are believed to change permeability: (1) changing effective stress due to the change of reservoir pressure caused by production or injection activities, and (2) strain caused by gas adsorption/desorption on the internal surfaces ofcoal.

CHAPTER 3

COAL BED METHANE

CHAPTER 3

3. COAL BED METHANE

Coal bed methane (CBM) is an environmental friendly clean fuel with properties similar to natural gas. Coal bed methane refers to methane adsorbed into the solid matrix of the coal. The presence of this gas is well known from its occurrence in underground coal mining, where it presents a serious safety risk. The methane content of a coal mine gas is 93-94%, the other notable constituents being ethane, carbon dioxide and nitrogen. Coal bed methane, often referred to as CBM, is distinct from typical sandstone or other conventional gas reservoir, as the methane is stored within the coal by a process called adsorption. The methane is in a near-liquid state, lining the inside of pores within the coal (called the matrix). The open fractures in the coal (called the cleats) can also contain free gas or can be saturated with water.

3.1FORMATION OF COAL BED METHANE

Coal Bed Methane (CBM), a hydrocarbon (CH_4) in gaseous form has its origin in the coalification process occurring over a period of millions of year out of accumulated plant material. During the stages of coalification methane and other gases are formed by chemical reactions such as dehydration, decarboxylation and dehydrogenation. And owing to the porous nature of coal these gases get adsorbed into coal matrix. And at the time of mining these gases are desorbed and emitted into mine workings. If these gases are not removed by proper ventilation then explosive mixtures will be accumulated inside the mines.

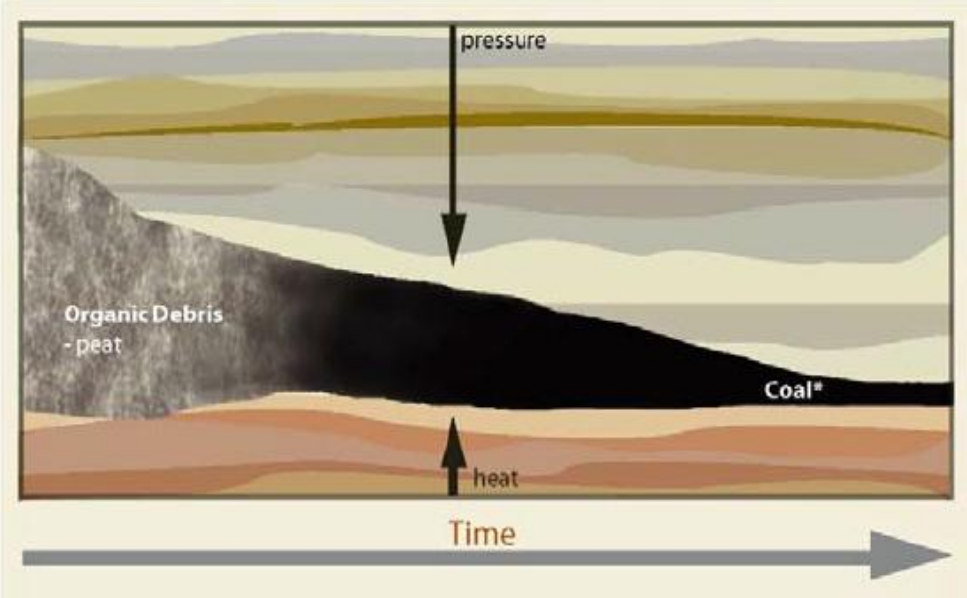

Figure 3.1 Formation of Coal

3.2 CLASSIFICATION OF METHANE IN COAL

3.2.1 Thermogenic Methane

Thermogenic methane isformed when organic matter (such as the remains of a plant or animal) is compressed under the earth, at very high pressure for a very long time. Thermogenic methane is formed from organic particles that are covered in mud and other sediment. Over time, more and more sediment and mud and other debris are piled on top of the organic matter. This sediment and debris puts a great deal of pressure on the organic matter, which compresses it. This compression, combined with high temperatures found deep underneath the earth, breaks down the carbon bonds in the organic matter. It is a Result of metamorphism of coal layers by pressure and heat due to increased depth of burial. Found in deep, marine sedimentary basins.

3.2.2 Biogenic Methane

Methane can also be formed through the transformation of organic matter by tiny microorganisms. This type of methane is referred to as biogenic methane. Methanogens, tiny methane-producing microorganisms, chemically break down organic matter to produce methane. These microorganisms are commonly found in areas near the surface of the earth that are void of oxygen. Formation of methane in this manner usually takes place close to the surface of the earth, and the methane produced is usually lost into the atmosphere. In certain circumstances, however, this methane can be trapped underground, recoverable as natural gas. It is biologically driven as a result of microbial action. It is found in shallow, freshwater sedimentary basins.

The CBM formed during the formation of coal.

$(C_6H_{10}O_5)_5$(Cellulose) = $C_{20}H_{22}O_4$ (Lignite) + $3CH_4$(Methane) + $8H_2O$ + $6CO_2$ + CO

$(C_6H_{10}O_5)_6$ = $C_{22}H_{20}O_3$ (Bituminous Coal) + $5CH_4$(Methane) + $10H_20$ + $8CO_2$ +CO

3.3 TYPES OF COAL BED METHANE

Virgin Coal Bed Methane (VCBM): Methane recovered from un-mined coal seams. The coal seams may be mined in the future but this is largely dependent upon geological factors such as coal depth and quality

Coal Mine Methane (CMM): Methane recovered during mining activities as the coal is in the process of being extracted and thus emitting significant quantities of the gas

Ventilation Air Methane(VAM): methane recovered from the ventilation network of a gassy mine is termed as ventilation air methane.

Abandoned Mine Methane(AMM): Methane recovered from mines that have been abandoned following the completion of mining operations. Significant amounts of methane may remain trapped in the mine or may continue to be emitted from openings.

3.4 CHARACTERISTIC PROPERTIES OF METHANE

Methane is also known as Carbureted hydrocarbon, firedamp, and marsh gas. High methane concentrations can cause oxygen-deficient atmospheres, flammable situations, or explosive environments. When methane enters the atmosphere as a point source, it can be readily ignited if the concentration exceeds 5 percent. Atmospheric methane can ignite at concentrations between 5 and 15 percent at Standard Temperature and Pressure (STP). Higher levels can quickly dilute to flammable levels. In either case, if methane is allowed to accumulate in an enclosed area, an explosive environment may develop. An explosive environment exists when a mixture of gases can self-propagate a flame throughout the mixture, independent of, and away from, the source of ignition. An ignition source can be an electrical outlet, pilot light, well pump, or match. Combustion requires fuel (methane), oxygen, and a source of ignition (Figure 3.2). Most methane problems are usually associated with confined spaces or enclosed structures where the gas can build up to explosive levels.
The explosive range for methane in air is normally quoted as 5 to 15% by volume, with the most explosive (stochastic) mixture occurring at about 9.8%. While the lower limit remains fairly constant, the upper explosive limit reduces as the oxygen content of theair falls. The flame will propagate through the mixture while it remains within the flammable range. Figure 3.3 illustrates a well-known diagram first produced by H. F. Coward in 1928 (McPherson, 1993).This can be used to track the flammability of air: methane mixtures as the composition varies.

In zone A, the mixture is not flammable but is likely to become so if further methane is added or that part of the mine is sealed off. In zone B, the mixture is explosive and has a minimum nose value at 12.2 percent oxygen. Zones C and D illustrate mixtures that may exist in sealed

areas. A mixture in zone C will become explosive if the seals are breached and the gases intermingle with incoming air. However, dilution of mixtures in zone D can be accomplished without passing through an explosive range.

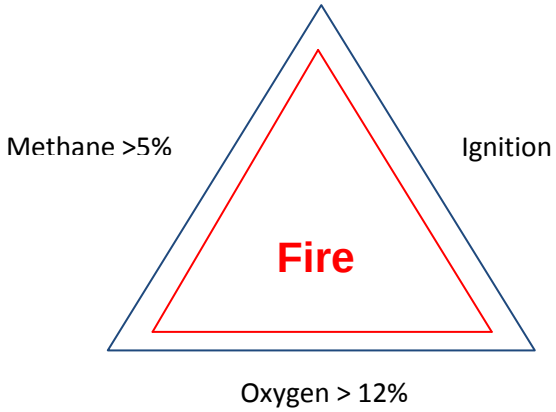

Figure 3.2 Fire Triangle for Methane

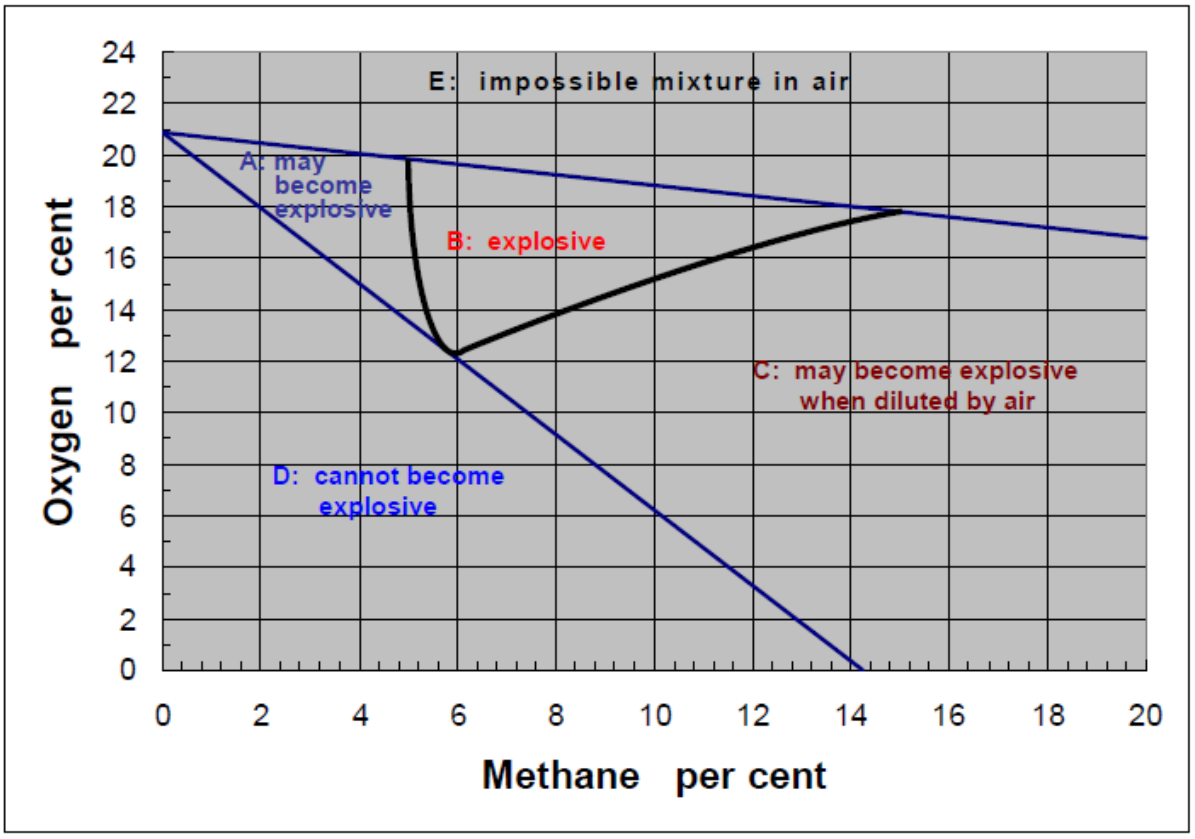

Fig. 3.3 Coward's Diagram for Methane in Air (McPherson, 1993)

3.4.1 Methane as a Green House Gas

Greenhouse gases when emitted to the troposphere allow sun-rays topenetrate to the earth but, due to specific properties of the gases, do notpermit all of the heat to reradiate back tothe atmosphere resulting in anincrease in temperature of the earth surface. Methane's contribution in globalwarming is 18% after CO_2 (66%) and followed by CFC (11%) and N_2O_5 (5%) (Prasad and Rai, 2000). Thus, Methane is a potent greenhouse gas secondonly to carbon dioxide as regards to its concentration by volume in theatmosphere. Methane has a global warming potential of 21 over a 100yearperiod. This means that on a kilogram for kilogram basis, methane is 21 timesmore potent than carbon dioxide during this time period. Its presentconcentration in atmosphere is 1.72 ppmv (which is double of itsconcentration in pre-industrial period) and increasing 0.015ppmv per year.Contribution of Indian coal mining is 0.4 million tonnes per year. It has beenestimated that reductions of about 10 percent in emissions would halt theannual rise in methane concentrations.

3.5 SOURCES OF METHANE IN COAL

Methane is stored in face cleats, butt cleats, natural fractures surrounding coal block matrix and pores, micro-pores within the coal block matrix. Methane is assumed to be stored mainly (>95%) in coal matrix pores, micro-pores in adsorbed state and very less amount (<5%) in bedding planes, natural fractures.The internal structure of coal showing the arrangement of cleats and fractures is shown in figures 3.4 and 3.5. Methane exists within coal in two distinct forms, generally referred to as free gas and adsorbed gas. The free gas comprises molecules that are, indeed, free to move within the pores and fracture network. Most of the CBM gas is in adsorbed state on the micro pores of the coal surface, thus coal is both the source and reservoir rock for CBM. A saturated CBM reservoir could contain up to five times the amount of gas contained in a conventional gas reservoir of comparative size, temperature and pressure. The amount of methane present in coal seams increases with rank of coal and depth of coal seams. A correlation study carried out at Central Mining Research Institute, Dhanbad, showed an increase of 1.30m^3/t in gas content per 100 m increase of depth. Along with other factors, the burial pressure mechanism, which helps form a coal, will also dictate how much gas a coal might still hold today and most coal basins illustrate a gas gradient whereincreasing depth generally shows corresponding increases in gas content. Free gas can be held within a coals' open pore system in this way at pressures exceeding 5 MPa (725 psi).

Any free gas within the coal interacts with the adsorbed gas and a state of equilibrium is created.

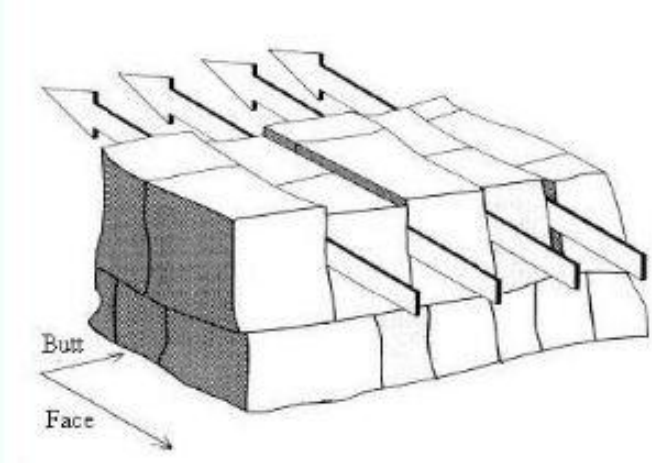

Figure 3.4 face and butt cleat in coal structure (http://www.uow.edu.au)

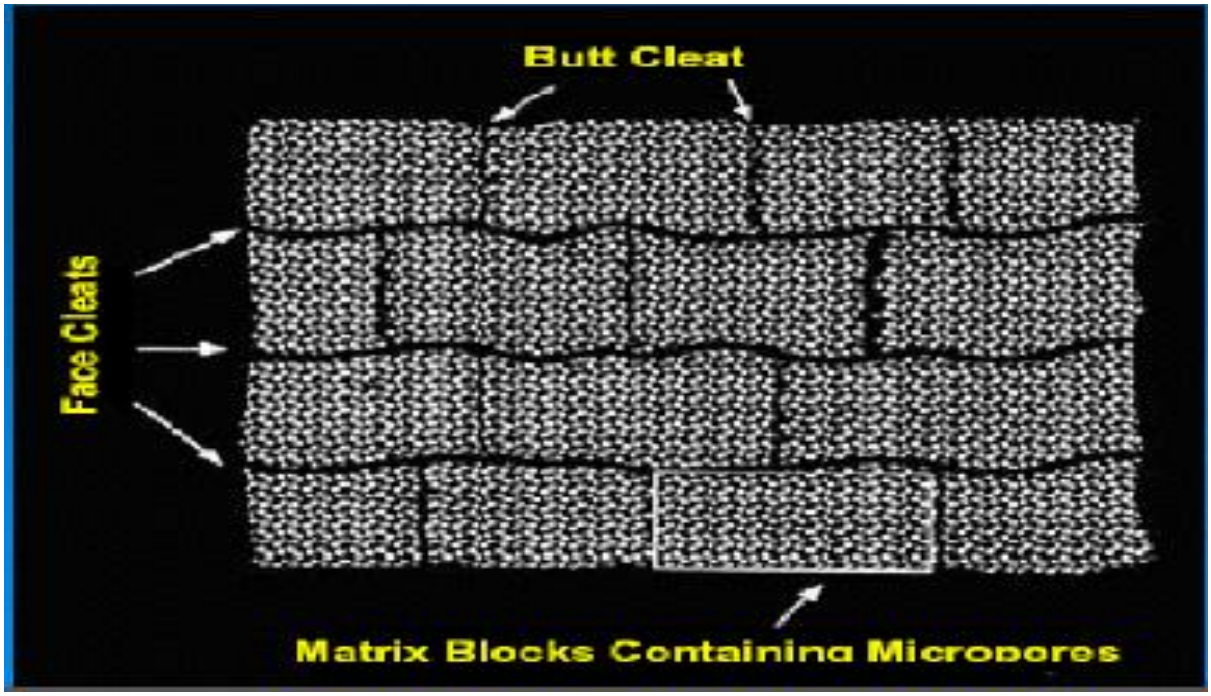

Figure 3.5 layouts of cleats and micropores in coal matrix (ars.sciencedirect.com)

3.6 PROCESS OF EMISSION OF METHANE

In the undisturbed state, equilibrium exists between free gas and adsorbed gas in the pores andfracture networks of coal. If, however, the coal seam is intersected by a borehole, or disturbed bymining, then the gas pressure gradient that is created will result in flow through natural or stressinducedfractures. The resulting reduced gas pressure in the pores will

promote desorption. In other words we can say if the binding pressure that traps the gases in coal is removed then gas emission takes place through diffusion. And this principle is followed during process of extraction of coal bed methane, where water pressure is the binding pressure and depressurisation by dewatering of seams is done to extract methane.

The rates at which methane are emitted into mine workings vary from near steady-state,throughcycles that mimic rates of mineral production, to the dangerous phenomena of gas outbursts or "sudden large emissions". In general, the rate of gas emission into the mine ventilation systemdepends upon:

- Initial gas content of the coal
- Degree of prior degassing by methane drainage or mine workings
- Method of mining
- Thickness of the worked seam and proximity of other seams
- Coal production rate
- Panel width (of longwall) and depth below surface
- Conveyor speeds
- The natural permeability of the strata and, in particular, the dynamic variations inpermeability caused by mining
- Comminution of the coal.

Variations in methane emissions into mines are influenced strongly by the dominant sources ofthe gas. In room and pillar workings, gas will be produced from faces, ribsides and the pillars ofthe seam being worked. While exposed pillars may be degassed fairly quickly (dependent uponthe coal permeability), ribside gas may continue to be troublesome for considerable periods oftime. In such cases, it is preferable for ribsides that border on virgin coal to be ventilated by returnair. Peaks of gas emission will, in general, occur at the faces of the rooms due tothe high rate of comminution caused by mechanized coal winning. This will be moderated by thedegree of earlier degassing, either by methane drainage or by gas migration towards theworkings. The latter is enhanced by high coal permeability and a low rate of advance.

In addition to ribsides, the major sources of methane in longwall mines are the working faces androof and floor strata. Ribside gas tends to be a slow and near constant source. It is convenient toclassify the other sources of methane in a longwall mine into face (or coal front) gas and gob gas.Peak emissions occur at coal-winning machines due to rapid fragmentation

of the coal. It is thisemission that gives rise to frictional ignitions at the pick point. The peak emissionmoves along a longwall face with the machine. However, the freshly exposed coal front will alsoemit methane – rapidly at first and decaying with time until the machine passes that point againCoal front gas is an immediate and direct load on the district ventilation system. Figure 3.6 isan example of a smoothed record of methane concentration in air returning from a longwall face.In this example, coal was produced on two out of three shifts for five days per week. The correlation of methane makes with face activity shows clearly, decaying down to a backgroundlevel over the weekend.Instress-induced permeability of roof and floor strata that create enhanced migration paths for thegas.

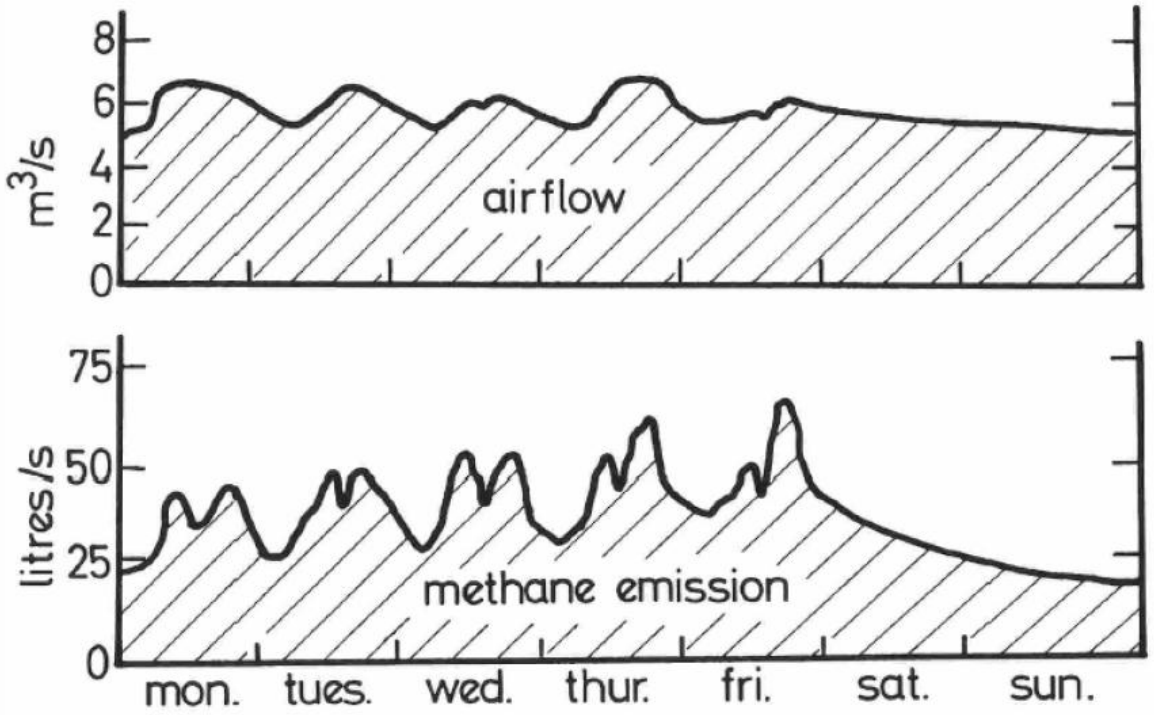

Figure3.6 Recordingsof Airflow and Methane Flow in an Airway Returning From a Longwall Face(McPherson, 1993)

The gas flow into the gob area behind a longwall face originates from any roof or floor coal that has not been mined from the worked seam, but more particularly from source beds within the roof or floor strata. Any coal seams or carbonaceous bands within a range of some 200 m above to 100 m below the working horizon are liable to release methane that will migrate through the relaxed strata into the gob area. If methane drainage is not practiced, then that methane will subsequently be emitted into the mine ventilation system. Figure 3.7 illustrates the variations

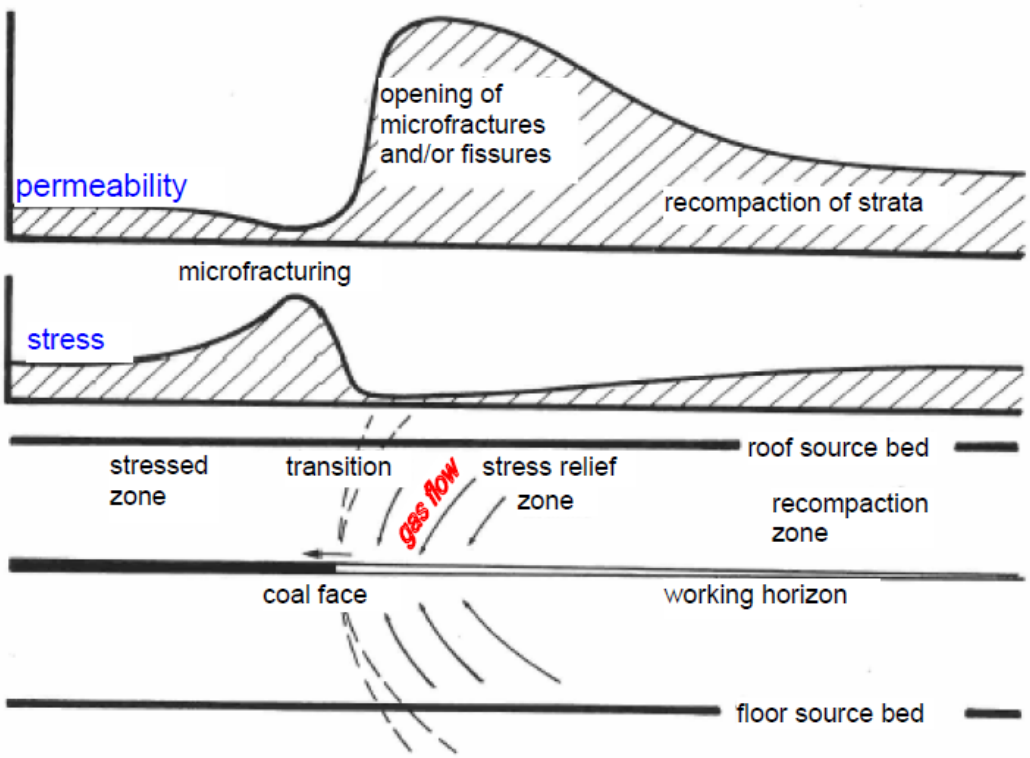

Figure 3.7: TheMigration of Gas from Roof and Flow Source Beds (McPherson, 1993)

3.6.1 Methane Layering

Methane emitted from the strata into a mine opening will often be at concentrations in excess of90%. While being diluted down to safe general body concentrations, the methane will,inevitably, pass through the 5 to 15% range during which time it is explosive. It is, therefore,important that the time and space in which the explosive mixture exists are kept as small aspossible. This can be achieved by good mixing of the methane and air at the points of emission.Unfortunately, the buoyancy of methane with respect to air (specific gravity 0.554) produces atendency for concentrated methane to collect in roof cavities and to layer along the roofs ofairways or working faces.

In level and ascentionally ventilated airways with inadequate airflow, the layer will stream alongthe roof in the direction of airflow, increasing in thickness and decreasing in concentration as itproceeds (Figure 3.8 (a)), Multiple feeders of gas will, of course, tend to maintain theconcentration at a high level close to the roof.There are two main hazards associated with methane layers. First, they extend greatly the zoneswithin which ignitions of the gas can occur. Secondly, when such an ignition has taken place, amethane layer acts very effectively as a fuse along which the flame can propagate –perhapsleading to much larger accumulations in roof cavities or gob areas.

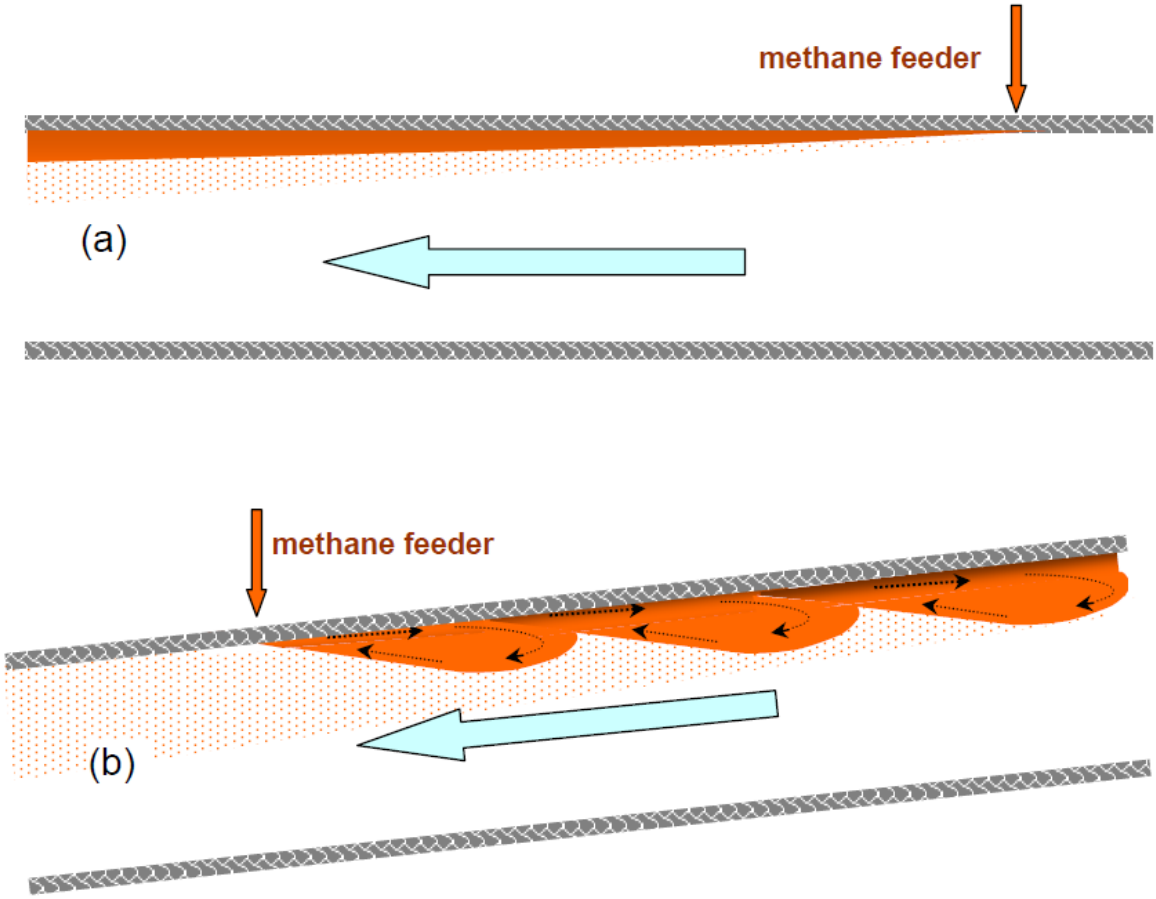

Figure 3.8 Methane Layering In (a) A Level Airway
(b) A Descentionally Ventilated Airway

Figure 3.8 (b) indicates that in a descentionally ventilated airway, the buoyant methane layermay stream uphill close to the roof and against the direction of the airflow. However, at the fringebetween gas and air, viscous drag and eddy action will cause the gas/air mixture to turn in thesame direction as the airflow. The result is that explosive mixtures may be drawn down into theairway upstream from points of emission.

3.6.2 Gas Outbursts

The most dramatic mode of gas emission into mine workings is the release of an abnormallylarge volume of gas from the strata in a short period of time. Such incidents have causedconsiderable loss of life. In many cases, the rate of emission has been explosive in its violence,fracturing the strata and ejecting large quantities of solid material into the workings. Gas outburstsare quite different from rock bursts that are caused by high strata loadings. However, theprobability of a disruptive gas release from adjacent strata is enhanced in areas of abnormallyhigh stress such as a pillar edge in overlying or underlying workings

There are two distinct types of gas outbursts, in-seam bursts and sudden large emissions from roof and floor.

3.6.2.1 In-seam Outbursts

As the name implies, these are outbursts of gas and solids from the seam that is currently beingmined. They have occurred in many countries, particularly in coal and salt (or potash) mines. Thegeologic conditions that lead to in-seam outbursts appear to be quite varied. The one commonfeature is the existence of mechanically weakened pockets of mineral within the seam and whichalso contain gas at high pressure. Methane, carbon dioxide and mixtures of the two have beenreported from in-seam outbursts in coal mines while nitrogen may be the major component inpotash mines (Robinson et al, 1981).

3.6.2.2 Outbursts from Roof and Floor

These are most likely to occur in longwall mines. As discussed earlier andillustratedon Figure 3.7, methane will migrate from higher or lower source beds towards the workinghorizon behind the working face. Strata in the stress relief zone normally exhibit a substantialincrease in permeability due to relaxation of the fracture network. The migration of gas thenproceeds through the overlying and underlying strata at a rate that follows cyclic face operationsand, under normal conditions, is quite controlled. However, a band of strong and low permeabilityrock (caprock) existing in the strata sequence between the source beds and the working horizonmay inhibit the passage of gas. This can result in a reservoir of pressurized gas accumulatingbeyond the caprock. Any sudden failure of this retention band will then produce a large and rapidinundation of gas into the working horizon (Wolstenholme et al, 1969).

3.7 CBM IN INDIA

India, having the fourth largest proven coal reserves in the world, holds significant prospects for explorationand exploitation of CBM. The total sedimentary area for CBM exploration in India is of the order of 26,000 sq. km. Out of this, exploration has been initiated in only 52% of the area. In other words, a large area remains to be explored.

Directorate General of Hydrocarbons (DGH) in close interaction with Ministry of Coal (MOC), carved out several prospective CBM blocks in different coalfields of the country, generated CBM related data and prepared Information Dockets & Data Packages. In May

2001, for the first time in the country, Government offered 7 blocks under 1st round of CBM bidding, out of which 5 blocks were awarded and contracts signed. Till date a total of four rounds of bidding have been carried out and a total of 33 blocks allotted.(http://www.dghindia.org).

3.7.1 CBM Policy

The CBM policy provides an attractive fiscal & contractual term, which is considered to be one of the best in the world, with freedom to work in a free and flexible working environment.

Some of the attractive terms offered by the Government are:

- No participating interest of the Government.
- No upfront payment.
- No signature bonus.
- Exemption from payment of customs duty on imports required for CBM operation.
- Walkout option at the end of Phase-I & II.
- Freedom to sell gas in the domestic market.
- Provision of fiscal stability.
- Seven years tax holiday.

The successful bidder would be required to enter into a contract with Government of India. There is scope of negotiation within the parameters laid down in the model contract.

Table 3.1 CBM Reserve Established as on 1st May, 2010

Sl. No.	Block name	Operator	Reserve Established (TCF)
1	SP (East)-CBM-2001/l	RIL	1.69
2	SP (West)-CBM-2001/l	RIL	1.69
3	Raniganj(South)	GEECL	1.385
4	Bokaro	ONGC	1.2
5	RG(East)-CBM-2001/l	ESSAR	2.15
	TOTAL		8.35

Table 3.2 Status of CBM Blocks as on 1st May, 2010

Blocks awarded till date	Nomination basis	3
	Under round-I	5
	Under round-II	8
	Under Round- III	10
	under round – IV	7
	Total	33
Status of Blocks as on date under	Exploration Phase-I	10
	Exploration Phase-II	8
	Development Phase-III	3
	Relinquished after Phase-	3
	Awaiting grant of PEL	2
Area awarded, sq. km	13,600	
Total CBM Resources, BCM	1374	
CBM wells drilled so far (Core Hole/Test well/ Pilot well)	300	
CBM reserve established (Gas Initial In Place), TCF/BCM for 4 blocks	8.4	
Expected Production Potential, MMSCMD	38	
Commercial Production commenced, w.e.f	14.07.07	
Approved gas sale Price,$/Mmbtu	6.79	
Present Gas Production from 3 blocks RG(S),SPI, & SP(W),MMSCMD	0.15	
Expected CBM gas production from 3 blocks by 2013 [Raniganj(S),SP I,SP(W)],MMSCMD	7.4	
State wise Blocks awarded	West Bengal	4
	Jharkhand	6
	Madhya Pradesh	5
	Rajasthan	4
	Chhattisgarh	3
	Maharashtra	1
	Gujarat	1
	Andhra Pradesh	2

As the third largest coal producer in the world, India has good prospects for commercial production of coal bed methane. Nevertheless, with demand for gas rising sharply, CBM

willhave to compete with imported (liquefied) natural gas. Methane is, however, a viable alternative to compressed natural gas (CNG) and its use as automotive fuel will certainly help reducing pollution levels.

India is one of the select countries which have undertaken steps through a transparent policy to harness domestic CBM resources. The Centre has received an overwhelming response from prospective producers with several big players starting operations on exploration and development of CBM in India.

3.8 POSITIVE AND NEGATIVE EFFECTS OF CBM

Over the past few decades, emissions of methane from coal mines have increased significantly because of higher productivity, greater comminution of the coal product, and the trend towards recovery from deeper coal seams. Under current federal coal mine regulations, methane must be controlled at the working faces and at other points in the mine layout. This has traditionally been performed using a well-designed ventilation system. However, this task is becoming more difficult to achieve economically in modern coal mines. In addition, scientists have established that methane released to the atmosphere is a major greenhouse gas, second only to carbon dioxide in its contribution to potential global warming. In order to improve mine safety and decrease downtime as a result of methane in the mine openings, many mines are now using a degasification system to extract much of the coalbed methane from their seams before or during mining. Methane drainage offers the added advantages of reducing the ventilation costs, reducing the development costs of the mine, reducing the global warming threat, and allowing a waste product to be productively utilized.

3.8.1 Mining-Related Economic Benefits of Coalbed Methane Drainage

There are many mining benefits that accrue from a methane drainage system. Methane drainage systems can: (1) enhance coal productivity because of less frequent downtime or production slowdowns caused by gas; (2) decrease fan operating costs because of reduced air requirements for methane dilution; (3) reduce shaft sizes and number of entries required in the mains, (4) increase tonnage extracted from a fixed-size reserve as a result of shifts of tonnage from development sections to production sections; (5) decrease dust concentrations due to reduction of velocities at the working face; (6) improve mine safety resulting from lower methane contents in the face, returns, gobs and bleeders; (7) reduce problems with water; (8) improve worker comfort through reduction of velocities in the working faces; and (9) provide miscellaneous other benefits

Negative effects – methane is a source of dangerous explosions in gassy mines. Methane is a major greenhouse, second only to carbon dioxide so its release has a negative effect on environment. Water extracted from seams during methane drainage is polluted and should be cleaned otherwise it can be harmful.

CHAPTER 4

EXPERIMENTAL INVESTIGATION FOR DETEREMINATION OF GAS CONTENT OF COAL

CHAPTER 4

4. EXPERIMENTAL INVESTIGATION FOR DETEREMINATION OF GASCONTENT OF COAL

4.1 SAMPLE COLLECTION

For gas content determination through extended desorption technique core samples had to be collected, but due to unavailability of core samples, freshly blasted coal blocks were collected. The freshly blasted coal samples were immediately sealed in a container then brought to the lab for experimentation. The details of the samples collected are as presented in table 4.1.

Table 4.1 Details of Samples Collected

Sample No.	Name of the mine	Coalfield/subsidiary
1	Lakhanpur	Mahanadi Coalfields ltd.
2	Basundhara	Mahanadi Coalfields ltd.
3	Kulda	Mahanadi Coalfields ltd.
4	Nadira colliery	Mahanadi Coalfields ltd.
5	Lingaraj	Mahanadi Coalfields ltd.
6	Bhubaneshwari	Mahanadi Coalfields ltd.
7	Dera colliery	Mahanadi Coalfields ltd.
8	Jagannath	Mahanadi Coalfields ltd.
9	Ananta	Mahanadi Coalfields ltd.
10	Bharatpur	Mahanadi Coalfields ltd.

4.2 EXPERIMENTAL METHODS FOR DETERMINATION OF GAS CONTENT

Gas content determination techniques generally fall into two categories: (1) direct methods which actually measure the volume of gas released from a coal sample sealed into adesorption canister and **(**2**)** indirect methods based on empirical correlations, or laboratory derived sorption isotherm gas storage capacity data. Direct gas content determination techniques may be further, subdivided into quick-crushing and extended desorption methods. The quick-crushing methods are primarily used in mine safety applications outside the United States, but have also been used for resource recovery applications. Quick-crushing

methodsrely on crushing the coal sample soon after collection to release all the desorbable gas, thus significantly shortening the amount of time required for desorption measurements. However, some data useful for resource recovery applications are lost. Extended desorption techniques are most commonly used for resource assessment and recovery applications where information on desorption rates is useful for reservoir modeling, and for fundamental coalbed methane research. Extended desorption methods allow the gases in the coal sample to desorb under controlled laboratory conditions until a defined low desorption rate cutoff point is reached. The sample may then be crushed to measure the amount of gas remaining within the sample.

4.2.1 Direct Methods

The gas content of a coal sample can be determined by several available direct measurementtechniques. These techniques can generally be divided into quick-crushing and extended desorption determination methods. The quick-crushing techniques are most commonly used outside the United States for assessment of gas conditions ahead of the active production face. The coal samples are usually obtained from underground drill holes. Instead of waiting for months to obtain results, total gas yield is available within a matter of days. Thus quick-crushing methods are appropriate for the mining applications for which they were intended. However, by crushing the sample early in the desorption process, it is impossible to determine the relative amounts of desorbed and residual gases, and the sorption time (time to release ***63%*** of total sorbed gas) commonly used in coalbed gas reservoir models (Sawyer et al., 1987). The extended desorption gas content measurement techniques allow for a sample to desorb gas until a low desorption rate cutoff point is reached. The sample may then be crushed to a powder to quickly release any gas remaining within the coal. These techniques are most common in the United States and are used for mining, coalbed methane resource recovery applications, and basic research. The coal samples to be tested are generally fresh core or drill cuttings obtained from boreholes drilled from the surface. Pressure coring is an alternative direct measurement method used to obtain a coal sample at reservoir pressure, thus eliminating the need for determining lost gas (Owen and Sharer, 1992). Pressure cores are generally considered the standard against which other gas content determination methods are evaluated. However, pressure cores are not without their own problems, including high cost.

This technique involves taking a sample of the seam from a borehole and placing it immediatelyinto a hermetically sealed container. The gas is bled off to atmosphere in stagesand its volumemeasured. The process is continued until further gas emissions are negligible.

An early method of direct measurement of gas content was developed in France (Bertrard etal, 1970). This utilized samples of small chippings from the borehole. Further researchcarried out bythe U. S. Bureau of Mines during the 1970's led to a procedure that used complete cores(Diamond, 1981). Although developed primarily for surface boreholes, the technique is applicablealso to horizontal holes drilled from mine workings. The sampling personnel must be present atthe time the hole is drilled into the seam. A stopwatch is used to maintain an accurate record ofthe elapsed times between which the sample length of strata is penetrated, start of core retrieval,arrival of the sample at the mouth of the borehole and confinement within the sealed container.

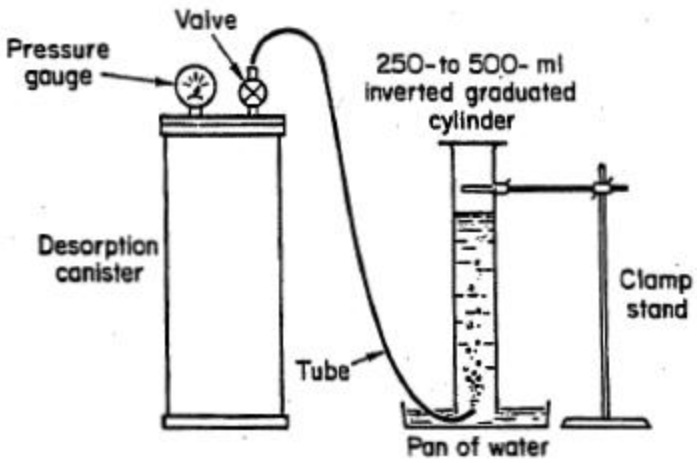

Figure 4.1USBM Direct Method Gas Volume Measurement Apparatus

Each container should be capable of holding about 2 kg of core and some 35 to 40 cm in length.Longer cores should be subdivided as a precaution against major loss of data should onecontainer suffer from leakage. The seals on containers must be capable of holding a gaspressure of 350 kPa without leaking. A pressure gauge should be fitted to each container.Gas is bled off from the container at intervals of time commencing at 15 minutes (or less if a rapidrise in container pressure is observed). The volume of gas emitted at each stage is measured,usually by water displacement, in a burette. The time intervals are increased progressively andthe process allowed is to continue until an average of not more than 10 cubic cm per day has beenmaintained for one week.

There is, inevitably, some gas lost from the core between the time of seam penetration and itsconfinement in a sample container. The volume of lost gas may be assessed by plotting thecumulative gas emitted from the container against time. The initial straight line may beextrapolated backwards through the recorded elapsed time of core retrieval in order toquantifythe lost gas. The retrieval time can be minimized by using wireline drilling. The techniqueisillustrated on Figure 4.2.

Another method of estimating the lost gasdeveloped by Smith and Williams (1984) makesseparate allowance for the elapsed times of drilling through the coal, core retrieval and periodspent at the mouth of the borehole before containment. This more sophisticated technique isbased on an analysis that takes account of the lack of uniformity in pore sizes (Smith andWilliams (1984a), Close and Erwin, (1989).

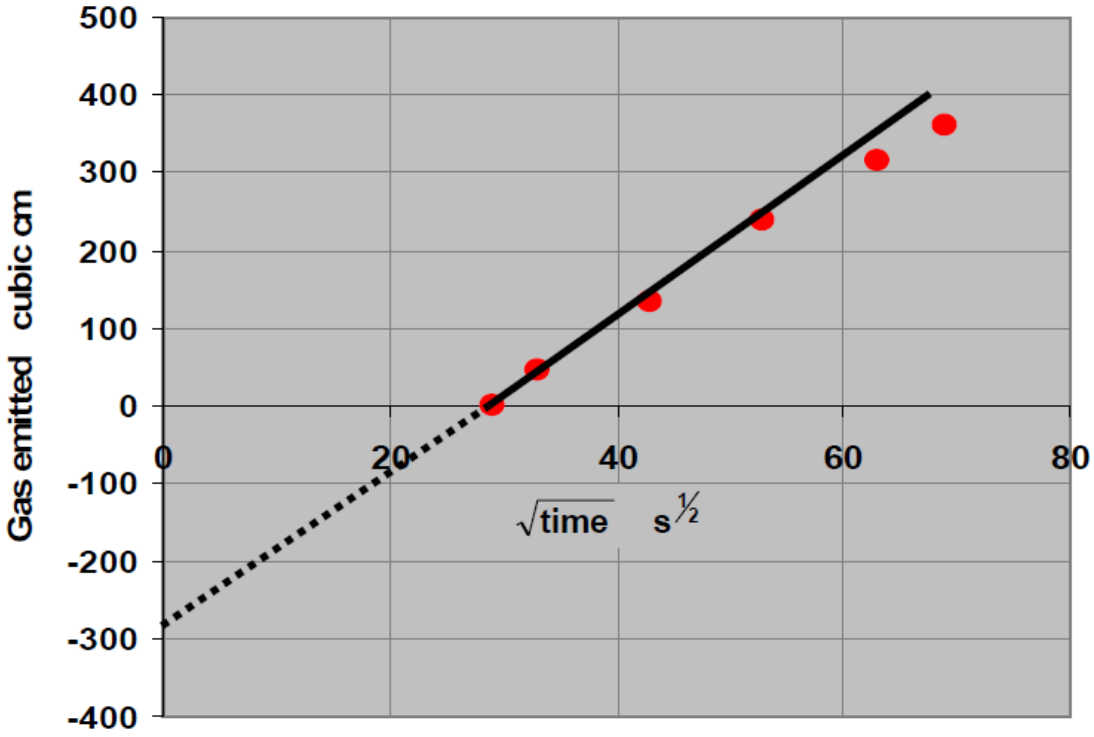

Figure 4.2 Assessment of gas lost during core retrieval

4.2.2 Indirect Methods (McPherson, 1993)

In this technique, representative chippings are obtained from the full thickness of the seam, mixed and ground to a powder of known particle size range. The sample is dried at a temperature of not more than 80°C and evacuated to remove the gases that remain in the pore structure. Unfortunately, the process of evacuation may alter the internal configuration of the

pore structure due to the liquefaction of tars. The phenomenon can be overcome by evacuating at low temperature – submerging the sample container into liquid nitrogen (-150°C) prior to and during the evacuation. After returning to the desired ambient temperature, methane is admitted in stages and the gas pressure within the sample container recorded at each increment. The volume of gas admitted may be monitored at inlet (volumetric method) or by measuring the increase in weight of the sample and container (gravimetric method). After correcting for free space in the sample container, a plot of cumulative methane admitted against pressure provides the total gas isotherm. If the porosity of the sample has been determined separately, then the results can be divided into free gas and adsorbed gas. The isotherms should, ideally, be determined at, or close to, the virgin rock temperature of the actual strata. If necessary, the curves can be corrected to seam temperature. At any given pressure, the quantity of gas adsorbed falls as the temperature increases. Starting at 26°C, the gas adsorbed decreases by some 0.8 percent per °C for bituminous coal and 0.6 percent per °C for anthracite. The curves should also be corrected to the actual moisture content of the seam using Ettinger's formula. In order to utilize the corrected gas isotherm, a borehole is drilled into the seam, either from the surface or from an underground location. In the latter case, the hole must be sufficiently long (10 to 20 m) in order to penetrate beyond the zone of degassing into the mine openings. Seals are emplaced in the borehole to encapsulate a representative length within the seam. A tube from the encapsulated length of borehole is attached to a pressure gauge and the rise in pressure is monitored. The rate of pressure rise will be greater for coals of higher permeability. The initial rate of pressure rise may be used in conjunction with open hole flow rates to determine in-situ permeability. However, for the purposes of assessing seam gas content, it is the maximum (or equilibrium) pressure that is required. Using this pressure, the gas content of the seam can be read from the corrected isotherm curve.

An advantage of the indirect method is that it gives the total gas content of the seam. However, this is not indicative of the actual gas that may be emitted into mine workings or recoverable by methane drainage. Furthermore, the measured in-situ gas pressure will be influenced not only by methane but also by other gases that may be present and, particularly, by the presence of water.

4.2.3 EXPERIMENTAL PROCEDURE

The freshly blasted coal samples were immediately sealed in a container then brought to the lab for experimentation. The samples were crushed and put into the desorption canister. The sample was heated at a very low heating rate to allow desorption of gas. The pressure developed inside the canister was noted down and then the valve of the canister was opened and gas was collected by downward displacement of water. The sample was allowed to desorb until a low desorption rate cut-off point was reached. The photographic view of the experimental setup is shown in Figure 4.3. The results of the gas content of the coal samples are as presented in Table 4.2.

Figure 4.3 Photographic View of the Experimental Setup of Extended Desorption Apparatus

Figure 4.4 Photographic view of different parts of extended desorption apparatus

Table 4.2 Results of the Gas Content of Coal Samples

Sample No.	W_0 (gm.)	W_1 (gm.)	T_i (^{0} C)	T_f (^{0} C)	V_i (ml)	V_f ml)	P(kg/cm^2)	V_d (ml)	G.C (m^3/tonne)
1	319	1275.5	20	41.5	12.5	60	0.04	47.5	0.05
2	319	903	22	46.7	15	160	0.12	145	0.248
3	319	1119	23.5	49.7	15	180	0.15	165	0.206
4	319	1072.5	26.5	49.6	15	260	0.21	245	0.325
5	319	1103	27	50	15	117.5	0.1	102.5	0.130
6	319	1086.5	28.9	50.2	15	95	0.07	80	0.104
7	319	1079	29.6	49.9	15	282.5	0.25	267.5	0.352
8	319	992	30.7	50.2	15	152.5	0.12	137.5	0.204
9	319	1064	33.7	53.1	15	90	0.06	75	0.101
10	319	1107	32	55	15	135	0.1	120	0.152

Where

W_0 = weight of empty container

W_1 = weight of (container + sample)

T_i = initial inner core temperature

T_f = finial inner core temperature

V_i = initial volume

V_f = final volume

P = pressure built-up in canister

V_d = difference in initial and final volume.

G.C = gas content of coal.

4.3 DETERMINATION OF PROXIMATE CONSTITUENTS OF COAL

4.3.1 Proximate Analysis (Is 1350 Part I -1984)

Proximate analysis was developed as a simple mean of determining the distribution of products that are found in coal. When the coal sample is heated under specified conditions, then it classifies the products into four groups: i) moisture; ii) volatile matter iii) fixed carbon, iv) ash, the inorganic residue remaining after combustion. For proximate analysis, i.e. for the determination of volatile matter, moisture, ash and fixed carbon, the method determined by IS (Indian Standard) 1350 (Part- I)-1984 was followed.

4.3.1.1 Determination of Moisture Content (M)

Coal is always associated with some amount of moisture, which is both physically and chemically bound, due to its nature, origin and occurrence. It is customary to differentiate between extraneous and inherent moisture. When a wet coal is displayed to atmosphere, the external moisture evaporates by sunlight, but the obviously dry coal still contains some moisture, which can be removed only on heating above 1000C that moisture is called air-dried or hygroscopic moisture. The quantity of external moisture counts mainly on the mode of occurrence and handling of coal, but the air-dried moisture is associated to the inherent hygroscopic nature of the coal.

Experimental Procedure

About 1g of finely pulverized -212 micron size air-dried coal sample is weighed in a silica crucible and then placed within an electric hot air oven.It is maintained at 110^0C.The crucible

with the coal sample is allowed to put in the oven for 1.5 hours and it is taken out with the help of tongues, then cooled in a desiccator for about 15 minutes then weighed. The loss in weight is reported as moisture (on percentage basis).

The calculation is done as per the following.

$$\% \text{ Moisture (M)} = \frac{Y-Z}{Y-X} * 100$$

Where,

X = weight of empty crucible, in grams (gm.)

Y = weight of crucible + coal sample before heating, in grams (gm.)

Z = weight of crucible + coal sample after heating, in grams (gm.)

Y -X = weight of coal sample, in grams

Y- Z = weight of moisture, in grams (gm.)

4.3.1.2 Determination of Ash Content (A)

During the ashing procedure, the coal ash is the residue left after the combustion of coal under defined conditions. It does not occur as such in the coal, but is formed as the result of chemical changes that take place in the mineral matter. Ash and mineral matter of coal are therefore not identical.

Mainly, the extraneous and inherent mineral matters are the two types of ash forming materials in coal. The extraneous mineral matter consists of materials like calcium, magnesium and ferrous carbonates, pyrite, marcasite, clays, shale's, sand and gypsum. The extraneous mineral matter builds on its origin by two types that are given below:

- The substances which got linked with the decaying vegetable material during its transition to coal, which is difficult to remove by mechanical methods,
- Rocks and dirt getting mixed up during mining and handling of coal.

The inherent mineral matter is the inorganic elements combined with organic components of coal. The origin of such materials is likely the plant materials from which the coal is formed. Ash from inherent mineral matter is unimportant as far as the total quantity of ash is pertained. But Indian coals suffer from the major disadvantage, that the mineral matter

content is not only high, but of intimately associated type, due to its drift origin. The several changes that occur, such as loss of water from silicate minerals, loss of carbon dioxide from carbonate minerals, oxidation of iron pyrite to iron oxide, and fixation of oxides of sulphur by bases such as calcium and magnesium. Because ash is quantitatively and qualitatively different from the mineral matter originally present in coal. In fact, combustion conditions determine the extent to which the weight change takes place and it is essential that standardized operations should be closely followed to ensure reproducibility.

Experimental Procedure

Weight of the empty crucible is taken. 1gm of desired coal sample is weighed in the crucible and is taken in a muffle furnace at 450 ^{0}C for 30 minutes and the temperature of the furnace is raised to 850 ^{0}C for one hour.

After that time interval, the crucible is taken out and placed in a desiccator and weighed.

% Ash (A) = $\frac{Z-X}{Y-X} * 100$

Where

X= weight of empty crucible in grams (gm.)

Y= weight of coal sample + crucible in grams (gm.) before heating

Z= weight of coal sample + crucible in grams (gm.) after heating

4.3.1.3 Determination of Volatile Matter (VM)

The loss of mass in coal, corrected for moisture, which results when coal is heated in specified equipment's under prescribed conditions in Indian standard, is referred to as volatile matter of coal. Some of the elements of coal that converted to volatile matter are hydrogen, carbon monoxide, methane and other hydrocarbons, tar vapours, ammonia, some organic sulphur and oxygen containing deepens and some incombustible gases, such as carbon dioxide and water vapour, all of which come from the decomposition of organic materials in coal. And inorganic materials in coal contribute the water of hydration of mineral matter, carbon dioxide from carbonates and hydrogen chloride from inorganic chlorides to the volatile matter.

Experimental Procedure

For determining the volatile matter a special volatile matter silica crucible (38mm height, 25mm external diameter and 22mm internal diameter) was used. First the empty silica crucible along with the lid uncovered was heated at 800 0C for an hour in the muffle furnace and then cooled to room temperature. The empty volatile matter crucible was then weighed again. Approximately 1gram of coal sample was weighed in the volatile matter crucible and it was placed inside the muffle furnace maintained at 925 0C with the lid covering the crucible. The heating was carried out exactly for 7 minutes, after which the crucible was removed, cooled in air and then in a desiccator and weighed again.

$$\% \text{ Volatile matter (VM)} = \frac{\mathbf{Y-Z}}{\mathbf{Y-X}} * 100 - \text{M}\%$$

Where X = weight of empty crucible, in grams (gm.)

Y = weight of crucible + coal sample before heating, in grams (gm.)

Z = weight of crucible + coal sample after heating, in grams (gm.)

Y -X = weight of coal sample, in grams (gm.)

Y- Z = weight of volatile matter + moisture, in grams (gm.)

4.3.1.4 Determination of Fixed Carbon (FC)

It is determined by subtracting the sum of all the above parameters (in air dried basis) and is given as:

Fixed Carbon (FC) = 100 - (M+ VM + A)

Where,

M = Moisture

VM = Volatile Matter

A = Ash content of coal.

The results of proximate analysis is as presented in Table 4.3

Table 4.3 Results of Proximate Analysis

Sample no.	M (%)	Ash (%)	VM (%)	FC (%)
1	5.31	50.22	23.69	20.78
2	3.64	23.67	32.23	40.46
3	3.05	34.01	26.30	36.63
4	5.39	12.26	35.34	47.01
5	5.40	18.42	33.98	42.20
6	4.85	11.53	41.26	42.35
7	4.23	10.74	41.85	43.18
8	5.46	19.00	35.57	39.97
9	5.43	23.29	32.23	39.05
10	7.23	21.91	34.64	36.22

CHAPTER 5

DISCUSSIONS AND CONCLUSION

CHAPTER 5

5. DISCUSSIONS AND CONCLUSION

5.1 DISCUSSIONS

The residual gas content of 10 coal samples collected from different mines of Talcher, Ib Valley and Basundhara area of Mahanadi Coalfields Ltd. (MCL) were determined following extended desorption method. The gas content of coal samples varied from 0.05 m^3/tonne to 0.352 m^3/tonne as shown in Figure 5.1.

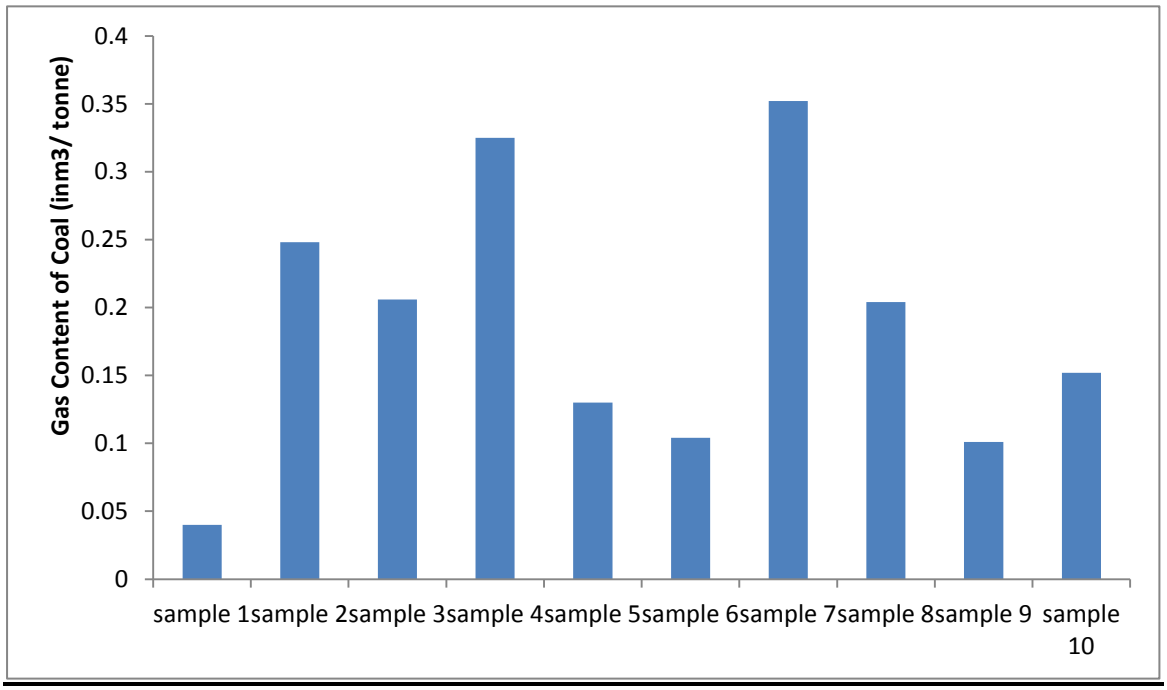

Figure 5.1: Plot of gas contents of coal samples

The gas content of coal sample from Lakhanpur opencast project was found to be 0.05 m^3/tonne, which is the minimum among all the collected samples. This is because the samples collected were cut coal samples of a surface miner. It is obvious that the sample size is finer; much of the free and adsorbed gas is released as the exposed surface area increases. Therefore it is possible that a large quantity of gases might have escaped before it was put in sample container and sealed.

The gas content of sample 4 (Nandira Colliery) and sample 7 (Dera Colliery) were found to be 0.325 m^3/tonne and 0.352 m^3/tonne respectively. These coal samples belong to underground workings which occur at greater depth than the rest of the samples. These have

greater amount of residual gas content as compared to the rest of the samples. This corroborates the fact that gas content of coal increases with depth.

The average residual gas content of Talcher area was found to be 0.195 m^3/tonne.

Correlation studies were carried out between the gas content of coal and the constituents of proximate analysis to evaluate the relationship of gas content in coal with some of the intrinsic properties. The constituents of proximate analysis, viz. moisture, volatile matter, ash content and fixed carbon (Table 4.3) were taken as independent variables; and the gas content of coal determined by extended desorption method (Table 4.2) was taken as dependent variables. The plots that have been obtained are as presented in Figures 5.2 to 5.5 along with the correlation coefficients.

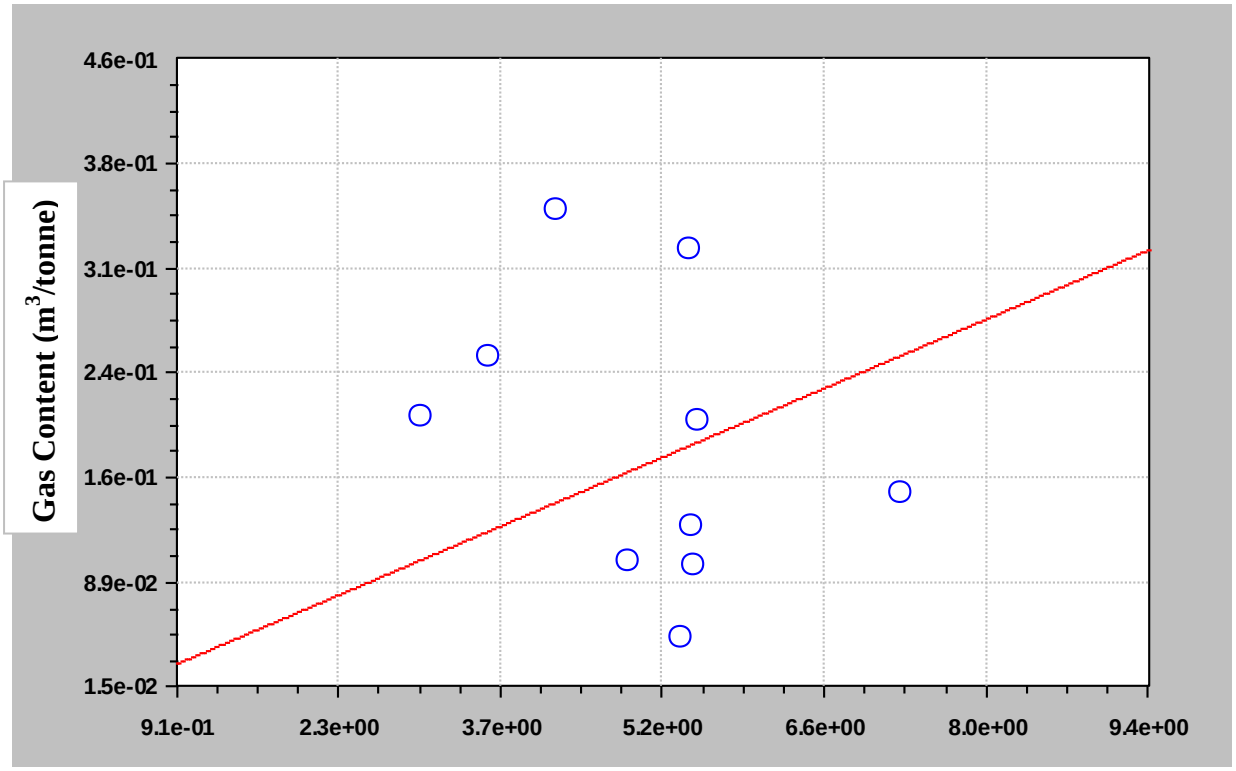

Figure 5.2: Relationship between Gas Content and Moisture (Corr. Coefficient=0.68)

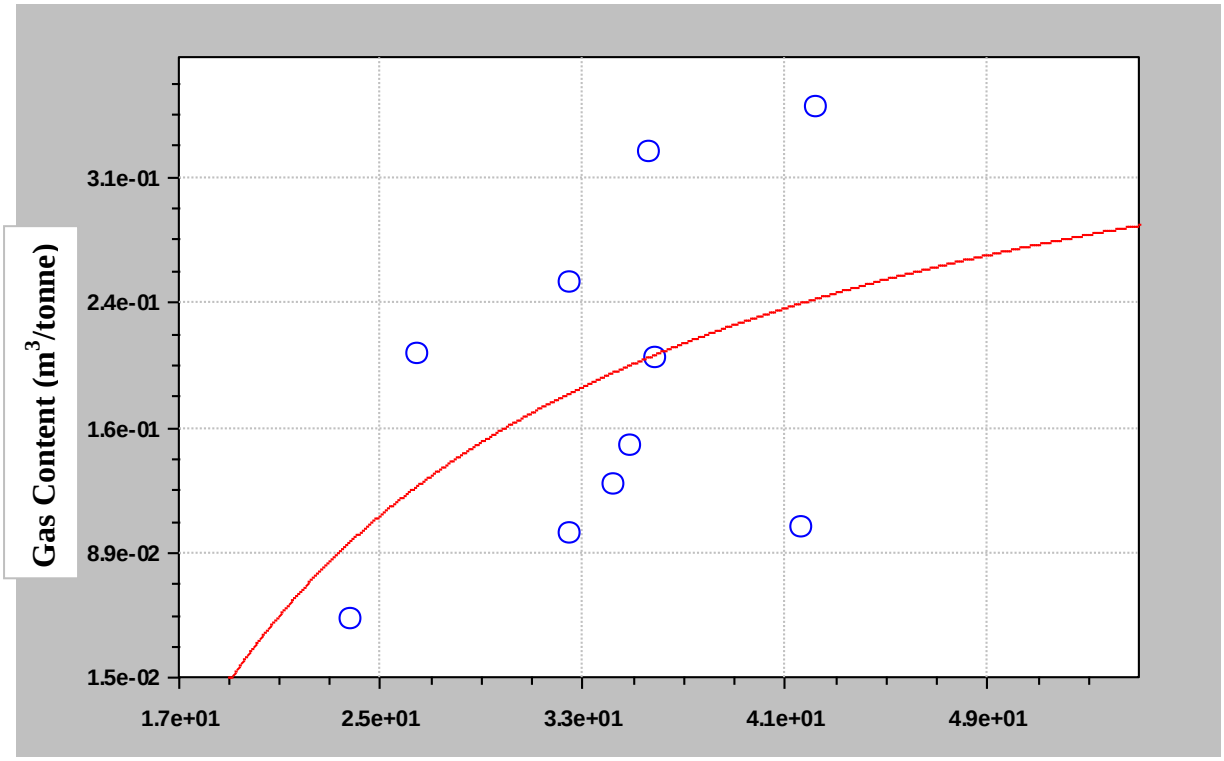

Figure 5.3: Relationship between Gas Content and Volatile Matter(Corr. Coefficient=0.50)

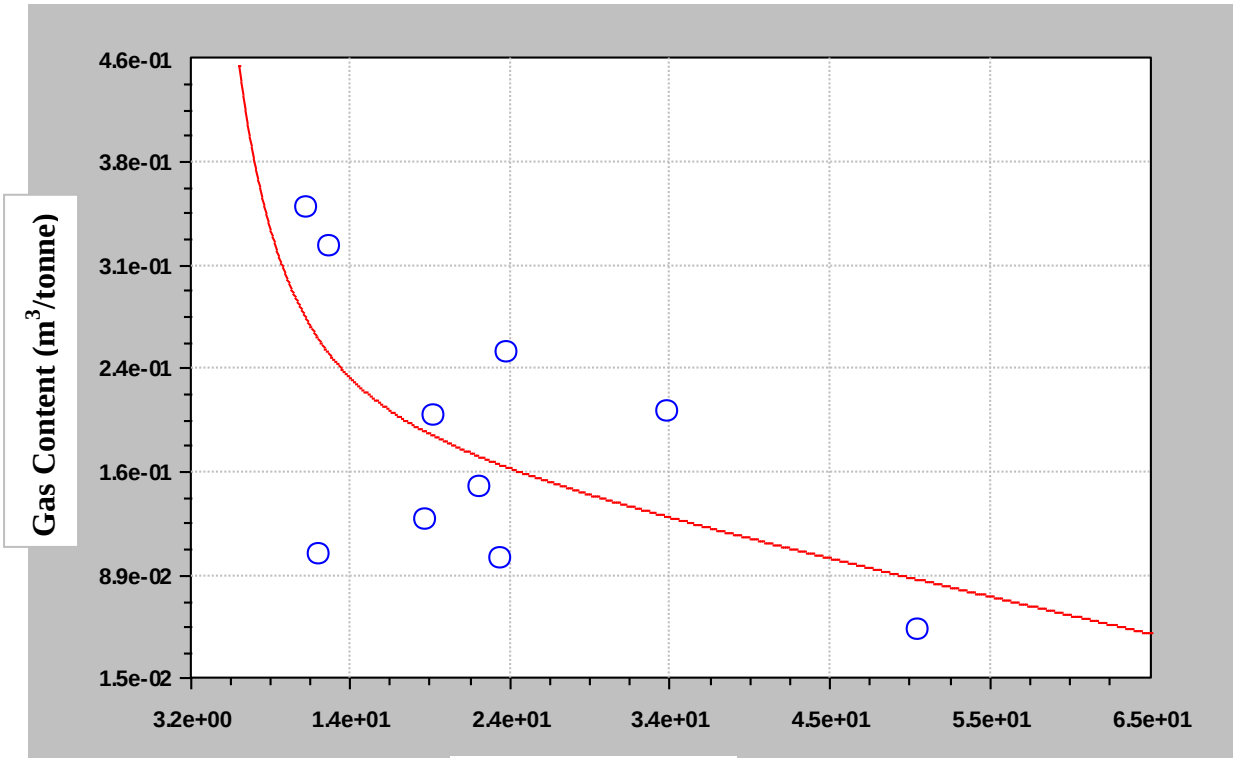

Figure 5.4: Relationship between Gas Content and Ash (Corr. Coefficient=0.58)

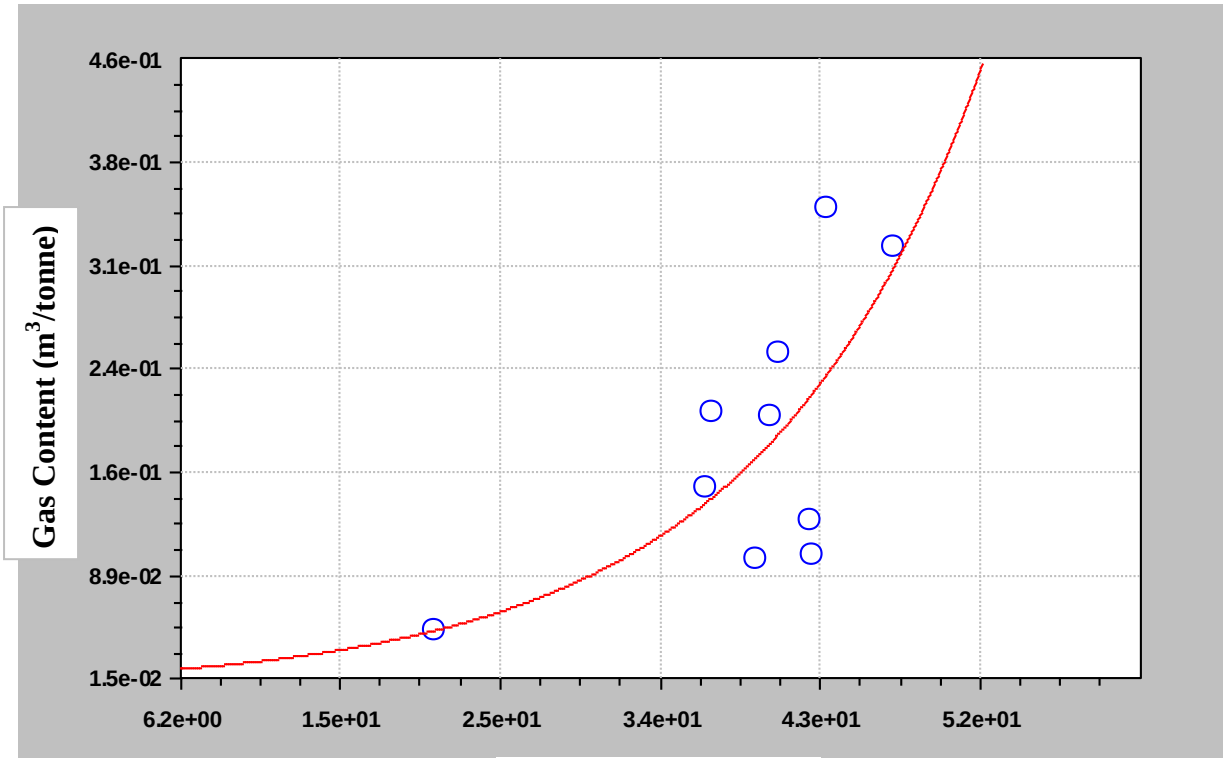

Figure 5.5: Relationship between Gas Content and Fixed Carbon (Corr. Coefficient=0.68)

The following observation may be made from the correlation study:

- The gas content of coal samples increases with moisture content (Figure 5.2). This could be because the gas remains confined in the pores and cracks in the presences of moisture.

- The gas content of coal samples increases with the increase in volatile matter content (Figure 5.3). Methane is one of the constituents of volatile matter content of coals. Therefore, with increase in volatile matter content, the gas content could be high. However, methane being lighter in specific gravity (0.559), much of it escapes if the coal seam is intersected/disturbed as in case of mining. The correlation coefficient could be low because of this reason.

- With increase in ash content, there is less gas content in the coal samples (Figure 5.4). This could be because of lesser amount of pore/void spaces in the mineral matter present in coal as compared to the coaly material.

- The gas content in coal increases with the fixed carbon content of coal samples (Figure 5.5). This could due to more amounts of voids and pore spaces in the coal with increased fixed carbon content.

5.2 CONCLUSION

If gas content of a coal seam is high, then it would be released to the general body of air during mining, creating hazardous atmosphere, particularly in underground coal mines. In such cases, steps should be taken to improve ventilation or drainage of methane should be carried out, so that the gas content is within permissible limits and does not create conditions for a fire or an explosion. If the gas content is found to be very high, then vertical bore holes may be put up to extract methane for a variety of commercial applications, starting from domestic heating to generation of electricity.

Because of practical difficulties, core samples from the coalfields could not be collected. Collection of core samples and the immediate determination of its gas content would help in finding out the exact amount of gas present in particular coal seam. This could not be done because of lack of core samples and therefore extended desorption method was adopted to find out the residual gas content in the coal samples. However, the present work gives some idea about the amount of methane present in the extracted coals from different mines of Talcher, Ib Valley and Basundhara area of Mahanadi Coalfields, which could be extended in future for a more detailed study. The mining activities particularly in underground mines could be planned in such a manner that the emission into workings is of minimum amount.

The extraction of methane in our country is in the beginning phase and there is a long road ahead to utilise the full CBM resources in our country.

CHAPTER 6

REFERENCES

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6.0 REFERENCES

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